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FIBER RING INTERFEROMETER NOISE STUDY.(U)
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(6) FIBER RING INTERFEROMETER NOISE STUDY.

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I. INTRODUCTION

All the present fiber ring interferometer gyroscopes are sensitive to changes in environmental conditions. This noise background, which is equivalent to a fringe shift of about ten times the earth rotation rate, is caused to a large extent by the polarization scrambling in the fiber and by the relative motion of the interferometer components.

One of the environmental changes is the variation of the birefringe due to small twists. A way of quantifying this effect on the state of polarization is to introduce controlled twists in a straight, relatively short (about one meter) fiber and determine the output polarization. Another environmental change is the variation of birefringence with temperature changes. An experiment to obtain quantitative results on these effects is described.

II. THE FIBER POLARIZATION EXPERIMENT

In our experiment (shown in Fig. 1) linearly polarized light is coupled into a fiber, with the plane of polarization rotating as a function of time. The light output of the fiber propagates through an analyzer, which rotates at 16 times the rate of the input polarization. The transmitted light is detected and the photodetector output is displayed on an oscilloscope. In such a display, the horizontal (time) axis corresponds to the input polarization angle. Orientations of the input polarization which yield linear output polarization correspond to regions where the oscilloscope trace oscillates between zero and 100% transmission. The output is elliptically polarized where the minima are greater than zero and the maxima less than 100%, and circularly polarized (corresponding to 90° phase shift) where the minima and maxima are equal in amplitude. In general, the phase shift between the linear-to-linear polarization channels, $\Delta\phi$, is given by

$$\Delta\phi = \left\{ 2 \tan^{-1} \left(\frac{P_{min}}{P_{max}} \right)^{\frac{1}{2}} \right\} \quad \text{Maximum over all input polarization orientations}$$

where P_{min} and P_{max} are the (local) minimum and maximum power transmitted through the output analyzer.

The setup illustrated in Fig. 1 is also provided with a means to rotate the output end of the fiber about its axis to produce a measured twist, SC79-6146

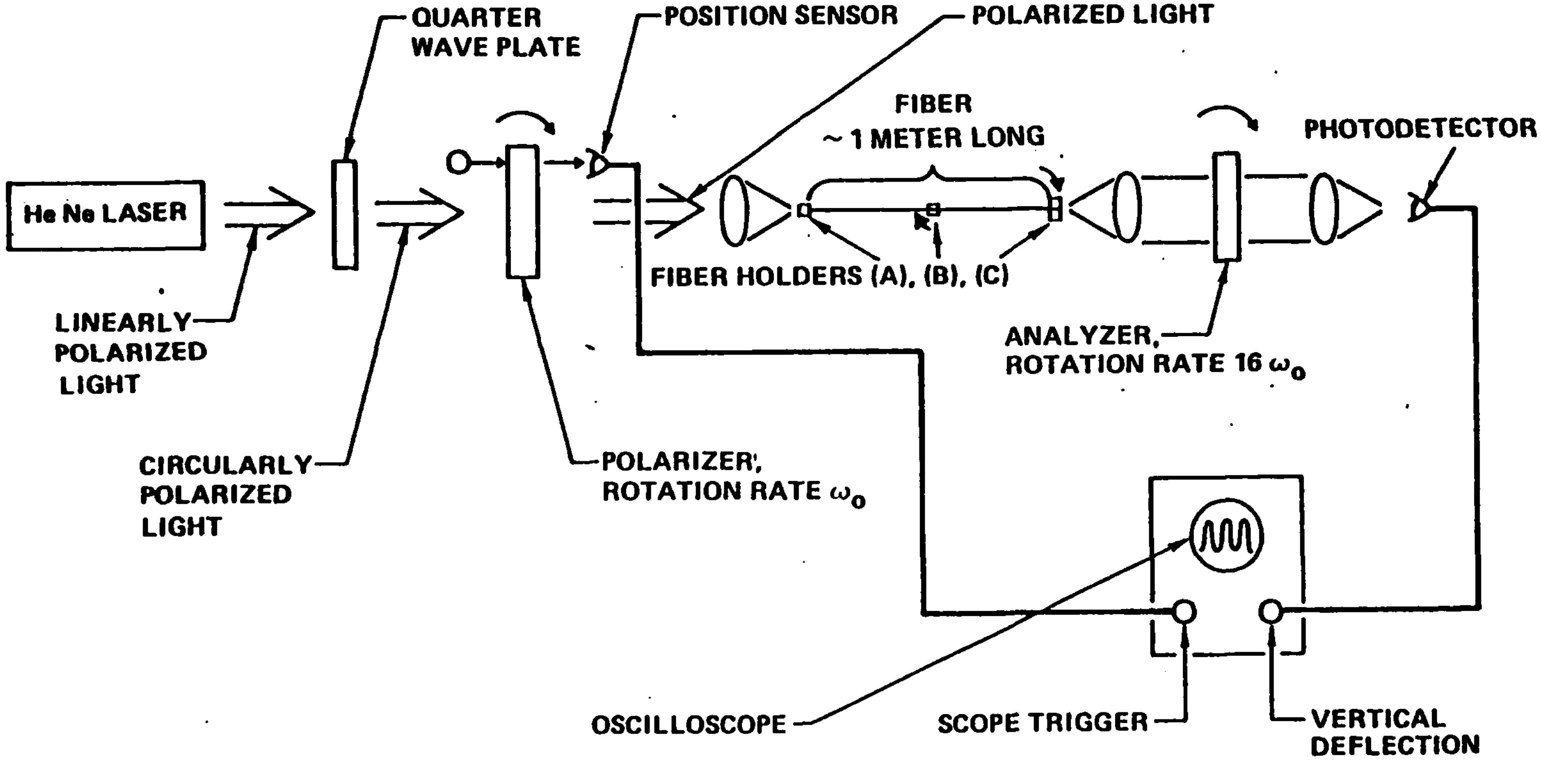


Figure 1. Experimental setup for investigating fiber polarization mode coupling effects. The photodetector output is displayed on an oscilloscope as a function of angular orientation of input polarization. Note the three fiber holders: (A) fixed, (B) for applying a mechanical perturbation midway along the fiber length, and (C) for twisting the fiber about its axis.

Two examples of oscilloscope tracings taken with this setup are shown in Fig. 2. The photographs correspond to two different twist angles 145° and 258° of the same single-mode circular core fiber. In Fig. 2 (a), the output polarization changes from linear to elliptical ($\Delta\phi = 44°$) as the input polarization is rotated. In Fig. 2 (b), the output polarization is almost circular ($\Delta\phi = 83°$) for a particular orientation of the input polarization. In order to display the evolution of the output polarization characteristics as a function of twist, a stepped motion picture camera is used to take a sequence of photographs of the oscilloscope, each corresponding to a different twist angle. The resultant "movie" presents a large amount of data in a form that can be readily analyzed.

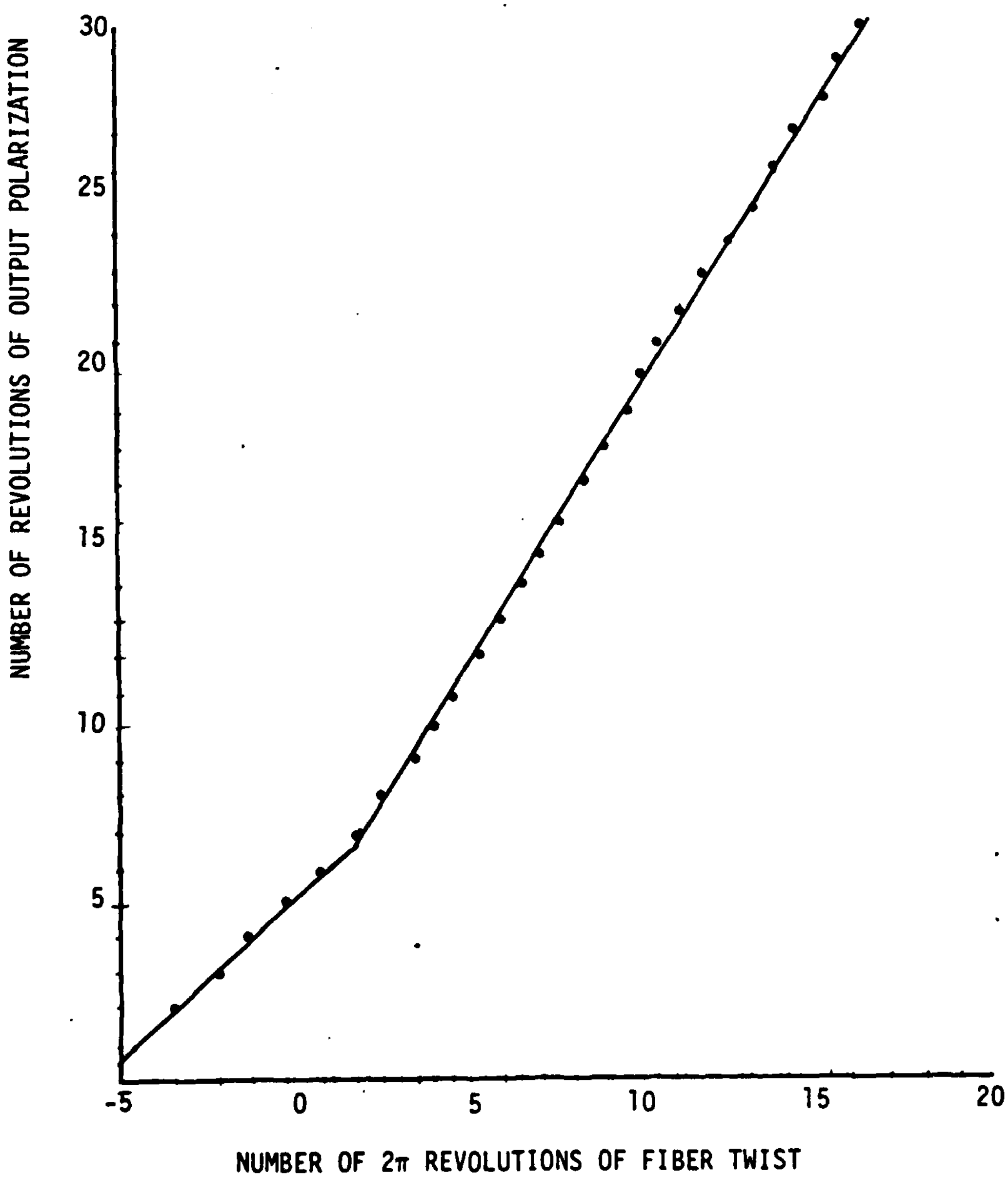
III. FIBER TWIST RESULTS

Two different fibers were used in this study: (1) ITT circular core fiber and (2) Bell Labs fiber with strain-induced birefringence. Figure 3 shows the dependence of the output polarization angle as a function of the fiber twist for ITT circular core fiber. The fiber was 112 cm long and was truly single mode at $\lambda = 6328$ Å. The fiber was held straight with about 50 gm force. An oscilloscope picture similar to Fig. 2 was taken for every 5° increment change of fiber twist. The twisting was started at about five turns in counterclockwise direction (with respect to light propagation direction) and changed through zero twist to about 17 turns in clockwise direction. There are two distinct slopes of this curve. For the first seven turns, the polarization twist slope was about 1. For the remaining 15 turns when the fiber was twisted in the opposite direction, the slope is 1.56. It is seen from the graph (Fig. 3) that the zero twist position was probably at about 7 turns from the starting position. It is also apparent (Fig. 3) that the slope of the output polarization angle versus twist angle has large random fluctuations. When such a fiber is used in a gyroscope, environmental variations produce unacceptably large-amplitude noise.

The Bell Labs fiber used in this experiment has the beat length of 3.3 cm, making the index difference between the fast and slow axes $\Delta n = 2.10^{-5}$. This is sufficient if one is somewhat careful not to bend the fiber too sharply (bend radius $< 1"$), or heat it too nonuniformly.[5] This fiber has

FIGURE 3

ITT FIBER
112 CM
50 GM TENSION
STARTING AT -5 TURNS
5° INCREMENTS



not changed its polarization maintaining properties measurably over a period of one year,[6] indicating that stress relaxation times in these fibers are quite long.

When this fiber is twisted, the plane of polarization follows the twist within the measurement accuracy. (Fig. 4). In this experiment one meter of fiber was used. Over a twist range of -4 to +10 turns, all the small-scale variations in the polarization turning rate were within the readout error. Overall polarization turning rate with respect to the mechanical fiber end turning was within 1% (the readout error). If the polarization maintaining fiber is used in the Sagnac ring interferometer gyroscope, the fiber will be reciprocal only if the direction of polarization coincides with the slow or the fast axes. Ohterwise the oppositely traveling beams do not see identical indexes of refraction in the same fiber cross section. [In previous experiments[1] the observed average index difference between oppositely traveling beams was $\sim 5.10^{-12}$]. The experimental polarization behavoir of the Bell fiber is compared with theoretical estimates using coupled mode theory in Section VI of this report.

IV. FIBER HEATING RESULTS

In another experiment the state of polarization at the output of the Bell Labs fiber was determined when thermal perturbation is applied.[5] The temperature of the fiber was temporally and spatially randomly varies ~20°C over 60 cm length. The polarizer was swept through an angle of about 90° for Fig. 5A (30 times) and about 180° for Fig. 5B (5 times). It is seen that at temperatures where the index difference between the fast and slow axes is such that the fiber behaves almost like a quarter wave plate, the exit phase varies quite drastically with the perturbation. However, when the direction of polarization of the light entering the fiber coincides with the fast or slow axes, the phase is unchanged by the external perturbation. These directions are marked in Fig. 5 with F .

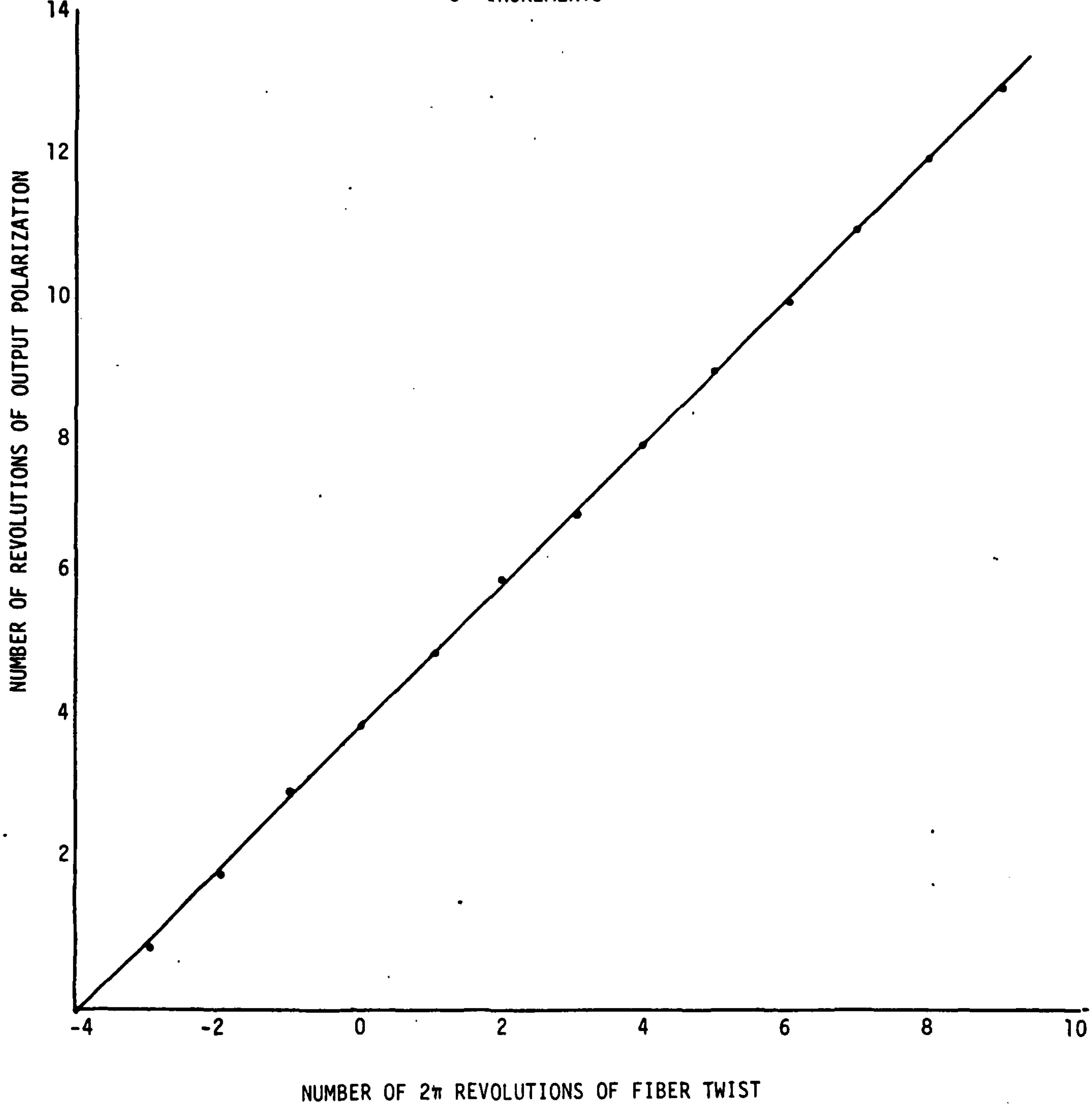
V. SAGNAC INTERFEROMETER NOISE STUDY

The next step will be using our 14 meter long Bell Labs polarization maintaining fiber in Sagnac interferometer configuration and measuring the fiber noise amplitude. Our Sagnac interferometer (Fig. 6) is built such that, using the bulk (non-fiber) optical beamsplitters, lenses and fiber end adjusters, the component motion is minimized. Also, to eliminate reflections, the optics is immersed on index matching fluid. Without this precaution the other (lower amplitude) noises would be unobservable.

FIGURE 4

BELL LABS FIBER

104 CM
NO TENSION
STARTING AT -4 TURNS
5° INCREMENTS



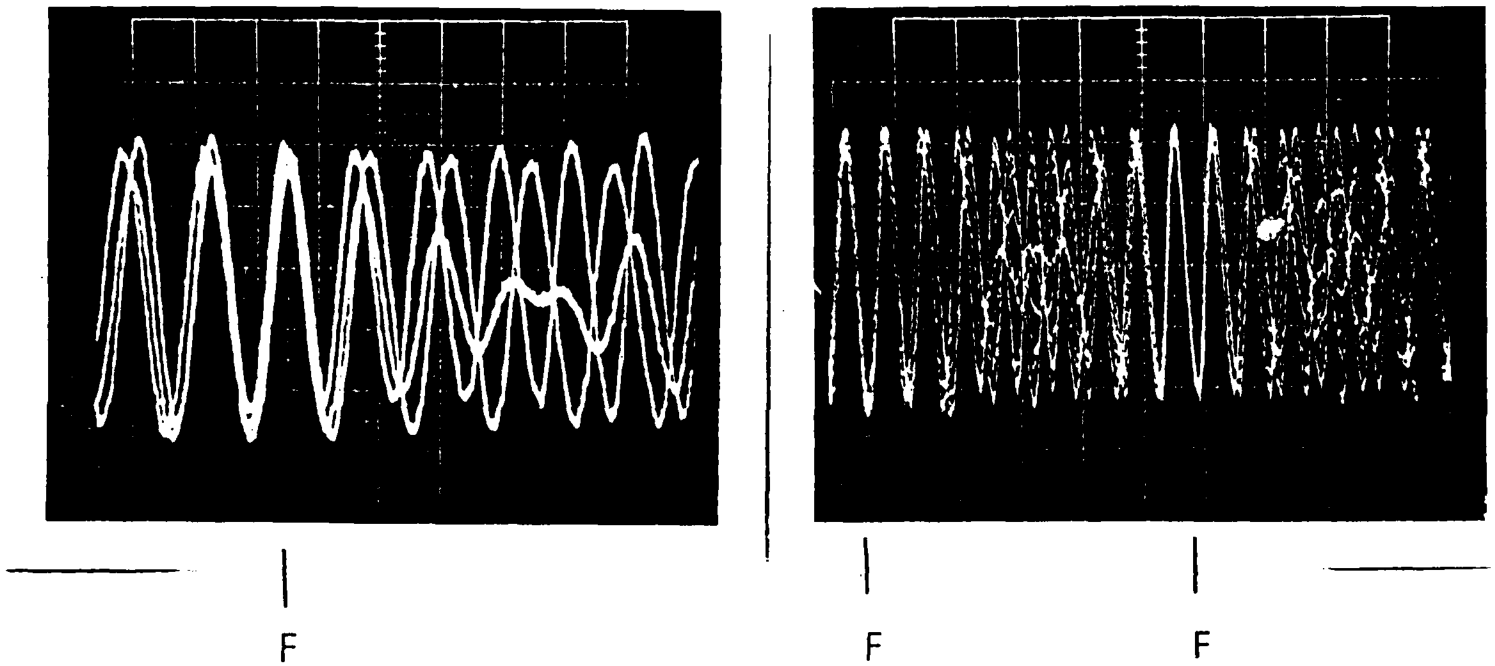


Figure 5. The behavior of polarization in Bell Lab's fiber when it is heated nonuniformly about 20°C. At slow and fast axis of the fiber the phase of polarization remains constant. (Points F).

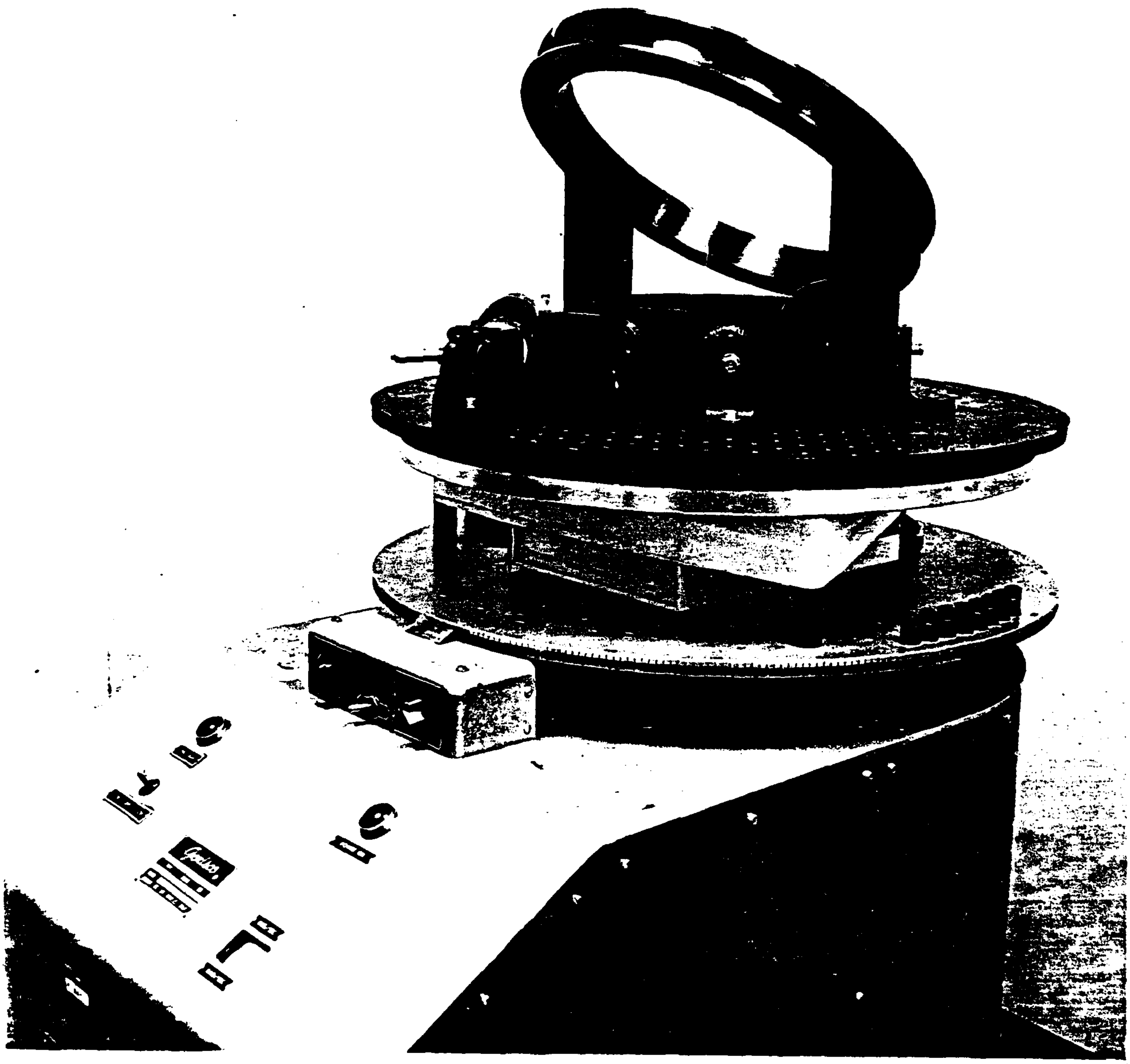


Figure 6. Sagnac fiber ring interferometer. It is mounted on a Genisco rate table. The minimum rate of the table is about 30°/hr. To be able to go below the earth rotation rate the fiber coil is mounted at an angle such that the plane of the coil can be made parallel to the earth rotation axis.

VI. COUPLED MODE THEORY FOR TWISTED FIBERS

Propagation of light in a twisted single mode fiber can be analyzed in a simple and straightforward manner using coupled mode theory. The fiber is assumed to be a birefringent medium with principal axes which rotate about the fiber axis as the end of the fiber is twisted. The coupled mode analysis considers the variation in amplitude of the two local round modes of the fiber as a function of distance along the fiber axis. The "weakly guiding" approximation is assumed, so that the polarization of the normal modes is approximately linear. Polarization vectors for these modes are directed along the axes of birefringence of the fiber, which are also the axes of the local coordinate system. The axes of the local coordinate system then rotate as the end of the fiber is twisted.

To characterize the fiber twist in terms of the coupled mode theory, it is useful to first consider the propagation of an incident wave through a birefringent plate of length δz. The light is assumed to propagate in the z-direction. The first plate is in contact with a second plate identical to the first, but with birefringence axes rotated through an angle $\delta\theta$ about the z-axis with respect to the first plate. Assuming that the incident wave amplitudes are a and b, corresponding to field components polarized along the respective axes of the first plate, the amplitude after transmission through that plate, a" and b", are given by

$$\begin{pmatrix} a'' \\ b'' \end{pmatrix} = \begin{pmatrix} e^{i\beta_a \delta z} & o \\ o & e^{i\beta_b \delta z} \end{pmatrix} \begin{pmatrix} a \\ b \end{pmatrix}$$

where β_a and β_b are the propagation constants corresponding to the respective axes of propagation.

Upon entering the second plate, the local normal mode amplitudes transform according to

$$\begin{pmatrix} a' \\ b' \end{pmatrix} = \begin{pmatrix} \cos\delta\theta & -\sin\delta\theta \\ \sin\delta\theta & \cos\delta\theta \end{pmatrix} \begin{pmatrix} a'' \\ b'' \end{pmatrix}$$

Combining these two matrix expressions, and retaining only terms to first order in $(\delta\theta)$ (δz), yields

$$\begin{pmatrix} a' \\ b' \end{pmatrix} = \begin{pmatrix} e^{i\beta_a \delta z} & -\delta\theta \\ \delta\theta & e^{i\beta_i \delta z} \end{pmatrix} \begin{pmatrix} a \\ b \end{pmatrix}$$

Thus, in the limit of small $\delta\theta$ and δz, this reduces to

$$a' = ae^{i\beta_a \delta z} - \delta\theta b$$

$$b' = \delta\theta a + be^{i\beta_b z}$$

If we let $A = ae^{i\beta_a z}$, $B = be^{i\beta_b z}$, then the difference equations above can be expressed in the differential forms

$$\frac{dA}{dz} = \kappa B e^{-i\Delta z} \tag{1}$$

$$\frac{dB}{dz} = -\kappa A e^{i\Delta z} \tag{2}$$

where $\kappa = -\frac{d\theta}{dz}$ and $\Delta = \beta_b - \beta_a$. Equations (1) and (2) are the coupled mode *equations, which are readily* solved in closed form if κ_{ab} and Δ are uniform in the z direction. The result is

$$\begin{pmatrix} A(z) \\ B(z) \end{pmatrix} = \begin{pmatrix} M_2 e^{-i\Delta z/2} & M_1 e^{-i\Delta z/2} \\ -M_1 e^{i\Delta z/2} & M_2 e^{i\Delta z/2} \end{pmatrix} \begin{pmatrix} A(o) \\ B(o) \end{pmatrix}$$

where

$$M_1 = \frac{\kappa}{\alpha} \text{Sin } \alpha z$$

$$M_2 = \cos \alpha z + \frac{i\Delta}{2\alpha} \text{Sin } \alpha z$$

$$\alpha = \sqrt{\kappa^2 + (\tfrac{\Delta}{2})^2}$$

Setting $A(o)=a$, $B(o)=b$, $A(z)=a'e^{i\beta_a z}$, $B(z)=b'e^{i\beta_b z}$

yields the even simpler expression

$$\begin{pmatrix} a' \\ b' \end{pmatrix} = \begin{pmatrix} M_2 & M_1 \\ M_1 & M_2^* \end{pmatrix} \begin{pmatrix} a \\ b \end{pmatrix} e^{-i(\beta_a + \beta_b)z/2}$$

relating the amplitudes of the local normal modes after propagating a distance z to the incident mode amplitudes.

The matrix equation above completely describes propagation in a twisted single-mode fiber. However, the value of κ given above must be modified to take into account the twist-induced circular birefringence term first observed and analyzed by Ulrich.[7] The modified expression is

$$\kappa = -\frac{d\theta}{dz}(1-g/2),$$

where g = 0.16 for silica fibers. It has also been tacitly assumed that the spatial variations in electric field amplitude are identical for the two orthogonally polarized local normal modes. This will not be true in the general case, but for weakly guiding fibers the correction for this effect can be considered negligible.

In general, if linearly polarized light is coupled into a single-mode fiber, the transmitted light will be linearly polarized, elliptically polarized, or circularly polarized. However, there are always two orthogonal orientations of the input polarization which yield a linearly polarized output. For the uniformly twisted birefringent single mode fiber, it is possible to determine the required rotation of input polarization in terms of the matrix element M_1 and M_2. To do this, we define new coordinate systems in input and output planes, rotated by angle θ_1 and θ_2 with respect to the original coordinate systems with axes parallel to the birefringence axes of the fibers. The amplitudes of the two polarization components of the input beam, a_1 and b_2, are related to the amplitudes in the output coordinate system, a_2 and b_2, by

$$\begin{pmatrix} a_2 \\ b_2 \end{pmatrix} = \begin{pmatrix} \alpha_2 & \beta_2 \\ \beta_2 & \alpha_2 \end{pmatrix} \begin{pmatrix} M_2 & M_1 \\ -M_1^* & M_2^* \end{pmatrix} \begin{pmatrix} \alpha_1 & -\beta_1 \\ \beta_1 & \alpha_1 \end{pmatrix} \begin{pmatrix} a_1 \\ b_1 \end{pmatrix}$$

where $\alpha_i = \cos\theta_i$, $\beta_i = \text{Sin}\,\theta_i$, i = 1,2. The amplitude a_1, b_1, a_2, b_2, are measured in the new, rotated coordinate systems. After performing the matrix multiplication, the preceding equation reduces to

$$\begin{pmatrix} a_2 \\ a_1 \end{pmatrix} = \begin{pmatrix} u & w \\ -w^* & v \end{pmatrix} \begin{pmatrix} a_1 \\ b_1 \end{pmatrix}$$

where

$$u = \alpha_2\alpha_1 M_2 - \alpha_2\beta_1 M_1 + \beta_2\alpha_1 M_1^* + \beta_2\beta_1 M_2^*$$

$$v = \beta_2\beta_1 M_2 + \beta_2\alpha_1 M_1 - \alpha_2\beta_1 M_1^* + \alpha_2\alpha_1 M_2^*$$

$$w = \alpha_2\beta_1 M_2 + \alpha_2\alpha_1 M_1 + \beta_2\beta_1 M_1^* - \beta\, \beta_1 M_2^* .$$

A linearly polarized output is obtained if either a_1 or b_1 equals zero, and $w = o$. The latter condition can be expressed as

$$\alpha_2\beta_2 M_{2r} + \alpha_2\alpha_1 M_{1r} + \beta_2\beta_1 M_{1r} - \beta_2\alpha_1 M_{2r} = 0$$

$$\alpha_2\beta_1 m_{2i} + \alpha_2\alpha_1 M_{1i} - \beta_2\beta_1 M_{1i} + \beta_2\alpha_1 M_{2i} = 0$$

After some use of trigonometric identities, we find that, if $w = 0$, then

$$\tan\,(\theta_2-\theta_1) = \frac{M_{1r}}{M_{2r}}$$

$$\tan\,(\theta_1+\theta_2) = \frac{M_{2i}}{M_{2i}}$$

Using our previous expressions for M_1 and M_2, it follows from these two equations that

$$\tan(\theta_1 + \theta_2) = 0, \text{ or } \theta_1 = -\theta_2$$

and

$$\tan(\theta_2 - \theta_1) = \frac{\kappa}{\alpha} \tan \alpha z. \qquad (1)$$

With w=0, the matrix expression above is diagonal, and the phase difference between u and v dtermines the maximum ellipticity of the output as the input polarization vector is rotated. Specifically, if $u = ve^{\pm i\psi}$, then if $\psi = N\pi$, $N = o, 1, 2, 3, \ldots$, the output polarization will be linear for any orientation of input polarization. On the other hand, if $\psi = (\pm N + \frac{1}{2})\pi$, $N = o, 1, 2, 3, \ldots$, the output polarization will be circular if the input polarization is oriented at 45° to the principal axes a_1 and b_1. For other values of ψ, the output will be elliptically polarized unless the input is polarized along the a_1 or b_1 axes.

In order to determine the phase shift ψ, it is first noted that $U = v^*$, so that, when $W = o$, we can write $U = e^{i\psi/2}$, $V = e^{-i\psi/2}$. But, from the definition of U,

$$U_r = \alpha_2\alpha_1 M_{2r} - \alpha_2\beta_1 M_{2r} + \beta_2\alpha_1 M_{1r} + \beta_2\beta_1 M_{2r}$$

$$U_i = \alpha_2\alpha_1 M_{2i} - \alpha_2\beta_1 M_{1i} - \beta_2\alpha_1 M_{1i} - \beta_2\beta_1 M_{2i}$$

which reduces to

$$U_r = \cos(\theta_1-\theta_2)\ M_{2r} - \sin(\theta_1-\theta_2)\ M_{1r}$$

$$U_i = \cos(\theta_1+\theta_2)\ M_{2i} - \sin(\theta_1+\theta_2)\ M_{1i}$$

But

$$\tan(\tfrac{\psi}{2}) = \frac{U_i}{U_r} \ ,$$

and since $M_{1i} = 0$ and, for $C = 0$, $\theta_1 + \theta_2 = 0$, it follows that

$$\tan\ (\tfrac{\psi}{2}) = \frac{M_{2i}}{\cos(\theta_1-\theta_2)\ M_{2r} - \sin(\theta_1-\theta_2)\ M_{2r}}$$

Substituting expressions for the matrix elements M_{1r}, M_{2r}, and M_{2i} yields the result

$$\tan\ (\tfrac{}{2}) = \frac{\frac{\Delta}{2\alpha}\ \mathrm{Sin}\ \alpha z}{\cos(\theta_1-\theta_2)\ \cos\alpha z - \sin(\theta_1-\theta_2)\ \frac{\kappa}{\alpha}\sin\alpha z} \tag{2}$$

From (1), it follows that

$$\sin(\theta_1-\theta_2) = -\frac{\kappa\frac{\Delta}{2}\sin\alpha z}{\sqrt{\kappa^2\sin^2\alpha z + \alpha^2\cos^2\alpha z}}$$

$$\cos(\theta_1-\theta_2) = \frac{\alpha\cos\alpha z}{\sqrt{\kappa^2\sin^2\alpha z + \alpha^2\cos^2\alpha z}}$$

so that (2) finally simplifies to

$$\tan\left(\frac{\psi}{2}\right) = \frac{\frac{\Delta}{2}\sin\alpha z}{\sqrt{\alpha^2\cos^2\alpha z + \kappa^2\sin^2\alpha z}}$$

The fiber output will be circularly polarized if $\psi = (N+\frac{1}{2})\,\pi$, $N = 0, \pm 1, \pm 2, \ldots$; which implies that $\tan\left(\frac{\psi}{2}\right) = \pm 1$. Thus, circular polarization will occur if

$$\left(\frac{\Delta}{2}\right)^2 \sin^2\alpha z = \alpha^2\cos^2\alpha z + \kappa^2\sin^2\alpha z,$$

or

$$\tan^2\alpha z = \frac{\alpha^2}{\left(\frac{\Delta}{2}\right)^2 - \kappa^2} = \frac{\left(\frac{\Delta}{2}\right)^2 + \kappa^2}{\left(\frac{\Delta}{2}\right)^2 - \kappa^2} \qquad (3)$$

It follows immediately from this result that the output cannot be circularly polarized in the limit of large τ, or more precisely, if

$$|\kappa| > \left|\frac{\Delta}{2}\right|$$

The theoretical result indicated in (3) is compared with experimental data on the Bell Labs polarization maintaining fiber in Table 1. The data was obtained by a frame-by-frame analysis of the oscilloscope tracing "movies" obtained by changing the twist angle in 5° increments, from about -4 turns to +9 turns. The twist angles which gave a circularly polarized output were determined as accurately as possible, and correspond to the data in the first column of that table. Next, a correction of .19 turns was added to each of those figures to make the twist angles corresponding to the most widely separated zero crossings symmetric about $\tau = 0$. This compensates for an apparent residual twist in the fiber. The values of κ correspond to $.92\tau$, or $.92 \times 2\pi = 5.78$ radians per turn. The final column is the value of τ for a circularly polarized output calculated from (3), using the value of $L = 210$ radians. This value of L was chosen because it gives a good fit to the data. The difference in effective refractive indices $(n_a - n_b)$

$$n_a - n_b = \frac{(\Delta L)}{2\pi L}$$

is calculated to be 2.1×10^{-5}, corresponding to a beat length ℓ_b of $\lambda/(n_a-n_b)$ of 3.3 cm for this fiber.

An effort was also made to analyze similar data for conventional, circular core fibers from ITT on the basis of the coupled mode theory. However, it was not possible to obtain a good fit to the data using the simple model.

Table 1. Comparison experimental data with calculated values for fiber twist angle which gives a circularly polarized output for some orientation of a linearly polarized input.

τ Experimental (Turns) UNCORRECTED	With Zero CORRECTED	κ(rad)	κ^2(rad^2)	τ Calculated (Turns)
-3.94	-3.75	-21.7	470	-3.81
-2.17	-2.08	12.0	145	-2.20
1.89	2.08	12.0	145	2.20
3.50	3.69	21.3	455	3.81
4.73	4.92	28.4	809	4.83
5.64	5.83	33.7	1136	5.76
6.50	6.69	38.7	1496	6.35
7.24	7.43	43.0	1845	7.18
7.99	8.18	47.3	2236	7.67
8.56	8.75	50.6	2558	8.34

The coupled mode theory can therefore be used with considerable confidence to explain the polarization behavior in polarization maintaining Bell fiber. However, because of the random distribution of stresses (produced during manufacturing process and by random bending, twisting and temperature variations) the polarization of ITT fiber is still intractable.

VII. PROPOSED FUTURE DEVELOPMENT

To eliminate the component motion completely, fiber beamsplitters are to be used. A suggestion for developing these and other fiber optic components is included with this report.

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February 16, 1980

Dr. David Lewis
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Dear David:

I am sorry about the delay in preparing the report on our Contract No. 79-1016, "Fiber Ring Interferometer Noise Study", with ONR. Some results are presented in the enclosed paper. For the case of Bell Labs polarization maintaining fiber, the coupled mode theory seems to explain our observations quite well. Henry Taylor wrote Section VI of this report concerning polarization behavior in stressed, twisted fibers. We have recently obtained some Andrew Corp. polarization maintaining fibe. with beat length of 2 - 3 mm and are in the process of comparing it with the Bell Labs fiber (It should be much better.).

I have also included with this report a suggestion for further work on reducing fiber gyroscope noise. It contains ideas for development of two important components left out of the RFP by the US Air Force (Solicitation No. F33615-80-R-1025, Wright-Patterson AFB, Ohio 45433). If it is of interest to you, we would like to submit a formal unsolicited proposal.

Sincerely yours,

Vic V.

Victor Vali

VV:cb

Enclosure

TASK DESCRIPTION

POLARIZATION PRESERVING FIBER BEAMSPLITTERS AND Y-JUNCTIONS

BACKGROUND

The photon noise limited accuracy of fiber Sagnac interferometer gyroscopes is sufficient to build inertial quality instruments. The maximum angular velocity uncertainty has to be less than 10^{-2} - 10^{-3} degrees per hour. To reach this accuracy all large noise sources have to be eliminated.

Good progress has been made in producing polarization maintaining fibers (R. B. Dyott, L. R. Corens, and D. G. Morris, Electronics Letters, 21th June 1979, Vol 15, No 13). Andrew Corporation plans to market such fibers (with beat length of 2-3 mm) in the first half of 1980. The use of these will eliminate the fiber polarization noise.

The next largest noise source we have identified is the interferometer component (beamsplitters, lenses, etc.) motion which is caused by environmental changes and acoustic pressure changes. This noise should be eliminated when fiber beamsplitters are used, since all of the fringe forming beam path is then in the fiber. Single mode fiber beamsplitters have been made (S. K. Sheem and T. G. Giallorenzi, Optics Letters, Jan. 1979, Vol. 4, No. 1). They are, however, suitable only in applications where polarization maintenance is not required.

For the low noise fiber Sagnac ring interferometer gyroscopes the polarization maintaining beamsplitters are essential. The study will, therefore, be concerned with developing a technique for making polarization maintaining beamsplitters and Y-junctions.

WORK TO BE PERFORMED

To preserve polarization in a fiber beamsplitter or a Y-junction, the fibers have to be joined at appropriate angles with respect to the fast or slow axes of the polarization preserving fiber. It is therefore suggested to use the polishing tethnique developed by J. Shaw at Stanford (FOSS) Workshop at NRL, Dec. 12-14, 1979, Washington D.C.) to remove the fiber cladding on one side and then fuse two such fibers with the polished (flat) sides touching. The fusing technique has been developed by M. McLandrich at NOSC (FOSS Workshop at NRL, DEC. 12-14, 1979, Washington D.C.).

In order to adapt these techniques for polarization maintaining beamsplitters and Y-junctions, it is necessary to construct a special fiber welder that contains a four degree of freedom (3-translational + 1 rotational) micromanipulator and a movable fiber welding arc gap. The moving speed, arc current and the gap spacing have all to be adjustable.

We think that suitable beamsplitters and Y-junctions are likely to be obtained using this technique. Therefore, the two largest contributors to the fiber gyroscope noise can be eliminated.

This program would require about one man-year.

Prepared by

V. Vali and M. F. Berg
February 15, 1980